Adaptive Snow Plow Routing Using Genetic Algorithm Artificial Intelligence

- James Zollweg, Ph.D.
  - Associate Professor, The College at Brockport
  - jzollweg@brockport.edu
  - Survivor of countless snowy winters in the vicinity of the three snowiest major cities in the USA
Learning Outcomes

- Broaden understanding of complexities and considerations involved in routing snowplows
- Recognize the potential of advanced computing technologies to reduce costs and improve service
- Consider the possibility of routings that vary from event-to-event depending on conditions (i.e. adaptive)
Snowplow Routing: the obvious

- Snow removal is a $3 Billion yearly expense in the USA, and is among the largest expenditures for many municipalities at a time when budgets are strained more than ever.
- Calculating optimum (or even near optimum) routes for a fleet of snow removal vehicles is extraordinarily difficult
Snowplow Routing: complications

- Unlike other vehicle routing problems, every street must be covered, in both directions.
- Street segments have varying priorities – cul-de-sac, local, collector, arterial.
- Snowplows are especially difficult vehicles to operate – U-turns and left turns are disadvantageous.
- Differences in intensity and duration of snowfall create vastly differing needs for snow removal.
- Road networks are complicated and illogical.
Snowplow Routing: characteristics of great solutions

- Minimizes total cost (directly related to miles driven)
  - Reduce ‘deadheading’
- Finishes job in acceptable length of time
  - Balance workload among operators
- Prioritize more ‘important’ roads
  - Time of day?
- Minimizes number of trucks used
  - Tradeoff between efficiency and completion time
- Avoid U-turns and left turns
- Closely linked to a GIS for effective I/O
Solutions to snowplow routing?

- The vehicle routing problem (VRP) is a long-studied topic with many variations and approaches
  - Traveling salesman problem
  - (Rural) Chinese postman problem
  - Capacitated VRP (road salt problem)
  - VRP with Pickup and Delivery
- **Much more difficult** is the multiple vehicle routing problem (mVRP)
mVRP requires allocation

- Need to divide the entire municipality into service areas, each handled by one plow
  - How to do this?
  - Can the workload be balanced among operators?
  - Since the process of allocation reduces the solution space, does it limit the efficiency of the final solution?
mVRP requires allocation

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YES!
What to do?

- Develop a method by which allocation and routing progress (evolve) simultaneously – A Genetic Algorithm
Genetic Algorithm

Possible solutions are ‘encoded’ as if they were chromosomes.

2-17-18-13-14-9-8-13-12-11-16-17-12-13-8-5-4-1-2-3-6-5-2-1-4-5-6-3-2-5-8-7-12-7-8-9-10-0
Crossover, Mutation

Homologous Chromosomes

Crossover (Prophase I)

Anaphase I

Chromosomal Mutations

Chromosomal mutations involve changes in whole chromosomes.
Genetic Algorithms applied

- An initial population of candidate solutions is created
  - In case of snow plow routing, plows are allowed random travel around town until all roads are plowed
  - Don’t need to be good, just complete
- A “fitness test” is applied to each solution
- The best solutions are “bred” to generate the next generation of solutions
- REPEAT
Empirical evidence

- Numerous ‘tiny-towns’ were divided up into service areas in a variety of ways – then each service area was routed
- Also, the genetic algorithm solution was applied to each tiny-town
- In each case, the genetic algorithm solution produced a better result
<table>
<thead>
<tr>
<th>Algorithm Used</th>
<th>Partitions</th>
<th>Total Distance Covered (mtrs)</th>
<th># of U-turns</th>
<th># of Repeated Road Segments</th>
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</thead>
<tbody>
<tr>
<td>Hand-Computed by Planners</td>
<td>6</td>
<td>345,153</td>
<td>45</td>
<td>2</td>
</tr>
<tr>
<td>GA (4 partitions)</td>
<td>NE</td>
<td>53,262</td>
<td>10</td>
<td>0</td>
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<tr>
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<td>NW</td>
<td>81,260</td>
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<td>2</td>
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<td></td>
<td>SW</td>
<td>57,199</td>
<td>11</td>
<td>0</td>
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<tr>
<td></td>
<td>SE</td>
<td>81,234</td>
<td>8</td>
<td>0</td>
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<tr>
<td></td>
<td>Total</td>
<td>272,955</td>
<td>37</td>
<td>2</td>
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<tr>
<td>GA (1 Partition)</td>
<td>Whole town</td>
<td>274,830</td>
<td>38</td>
<td>34</td>
</tr>
</tbody>
</table>
Feedstock - OpenStreetMap
V. of Brockport – GIS roads data set
Plow Route #4
SHOW ANIMATION
How this might be used

- Run the GA SPR at the start of every event to optimize the number of plows and their routing
  - Snowfall rate
  - Expected storm duration
  - Time of day
- Generate turn-by-turn GPS instructions for operators
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